R-723 – An Azeotrope on the Basis of Ammonia

Apart from the refrigerants, the refrigeration oils are important working materials in refrigeration systems. In a closed cycle the oil has to be transported back to the compressor. At low temperatures the oils become viscous or even reach their pour point and become solid. The manufacturers of refrigeration systems have for long addressed this problem by using refrigeration oils which have a good solubility with the refrigerant thus reducing the viscosity of the oil by magnitudes.

In the 1990s soluble oils on the basis of polyalkylene glycol had also been developed for ammonia and been used successfully in many systems. However, there was also an increasing number of problems with the internal stability of the refrigeration cycle. This is essentially caused by the hygroscopicity of the oil, which can lead to a complete miscibility with water. In connection with high temperatures and high moisture this may result in instabilities in the refrigeration cycle – especially in the presence of aluminium materials –, which can lead to the failure of the refrigeration system.

Therefore, tests were conducted, in which a gaseous substance was added to ammonia as a "solubility agent" in order to achieve a good oil solubility with conventional mineral oil. First successful attempts were carried out with ammonia-amine mixtures, which did increase the oil behaviour considerably but had the disadvantage of causing problems in the refrigeration cycle due to their strong non-azeotropic behaviour.

Another additive to be investigated was dimethyl ether, a solvent widely used in the chemical industry. It is deployed as propellant in many sprays. As a refrigerant, it is similar to isobutane. Investigation of the miscibility behaviour of ammonia unexpectedly revealed that the two substances form an azeotrope. The ammonia concentration of the azeotrope is 60 mass percent. This means that the mixture can be treated as a pure substance within the range of this concentration, without any shift in concentration occurring during condensation and evaporation or leakages. As the molar mass of the mixture is 23, it was named as refrigerant R723, which is appropriate based on the refrigerant nomenclature for naturally occurring refrigerants. However, the name R723 does not correspond to the official nomenclature pursuant to ISO817, although it has meanwhile become established language usage among refrigerant experts.

This mixture is still not officially listed in DIN EN 378, as this has to be preceded initially by complex registration and issuing of an R-number.

Apart from the improved oil solubility which was initially seen as the crucial factor, R-723 has various other positive properties, which have been investigated in several projects and also been confirmed in a number of practical tests.

Figure 1 shows the vapour pressure of the mixture in comparison to ammonia. The vapour pressure is seen to correspond almost with that of ammonia and is slightly higher only at low temperatures.

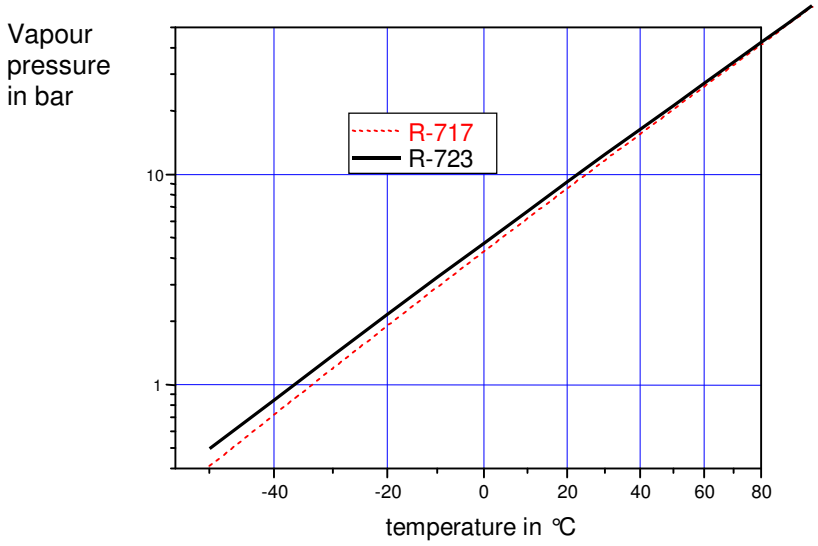

Figure 1: The vapour pressures of R-717 and R-723 as a function of temperature

This means that the compression ratio is smaller at the same evaporation and condensation temperatures as can be seen in figure 2.

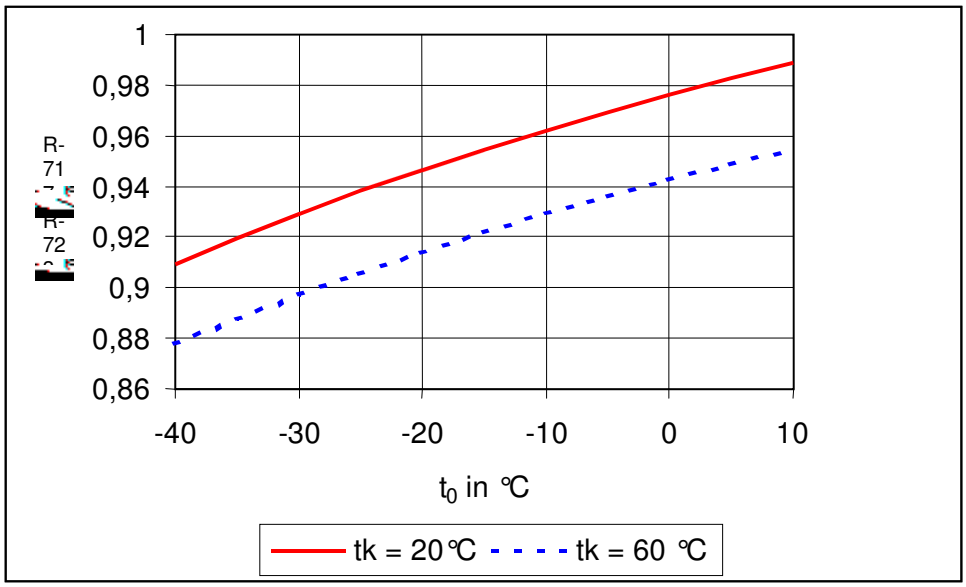

Figure 2: Relative pressure ratio

As the adiabatic exponent of the mixture is smaller due to the higher molar mass, a lower compression temperature needs to be expected as well (figure 3).

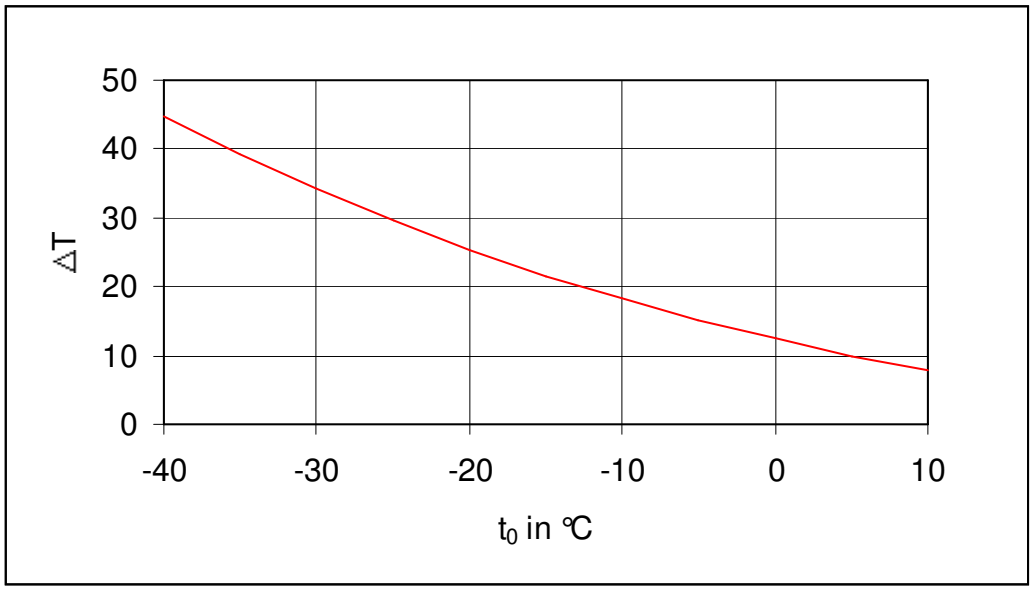

Figure 3: Difference in the compression temperature between ammonia and R273 at a condensation temperature of 40 °C

Important properties are the greater volumetric refrigeration capacity and also the higher COP values in comparison to ammonia. This difference to pure ammonia deserves special attention in TEWI evaluation of refrigeration systems. In refrigeration systems which had initially been operated with ammonia and later with R-723, the COP value improved by 7%.

Additionally, it needs to be pointed out that when using mineral oils with the mixture, considerable improvements of the heat transfer coefficient could be achieved at dry evaporation due to the application of the mixture.
The property data of R-723 are contained in the property data programme for ASERCOM.
Purely in terms of its lower explosion limit of 6.0 volume percent, the mixture would belong to group L2 pursuant to DIN EN 378 (toxic and flammable) like ammonia, so that it would be treated like ammonia with regard to safety. The second parameter relevant to classification, which is the specific combustion heat (i.e. the energy released only on burning) amounts to 22800 kJ/kg which is above the limit value of 19000 kJ/kg arbitrarily defined for group L2. Accordingly, it would then have to be classified in group L3 like R290 (propane). As things stand, classification pursuant to ASHRAE standard 34 will probably lead to the latter.

Safety requirements often limit the refrigerant charge in ammonia systems. In relation to an equal ammonia charge, considerably better refrigeration capacities can be achieved with R-723.
Substances that are suitable for ammonia can also be used for the mixture. However, when using elastic polymer materials as sealants, these should be tested for sufficient resistance to dimethyl ether from case to case in the event of any possible direct contact with the product. All major component manufacturers have subjected to the product to early testing and have been able for some time now to offer the full range of components necessary for refrigeration systems with R723 as working fluid.

R723 can be used above all for new systems also with smaller refrigerating capacities well below 100 kW because the circulating volume flow in the vapour phase is about 150% compared to ammonia, resulting in acceptable piping cross sections and flow velocities even for smaller refrigerating capacities.

The refrigerant has been on the market for several years and can be purchased in Germany through selected refrigerant distributors.

Further publications:

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Use of Ammonia/Dimethyl ether (schick R723®) Blend in Medium Refrigeration Plants

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